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Generation of ultrasound by achiral ferroelectric liquid crystal film

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The piezoelectric effect was discovered by the Curie brothers in 1880. The practical use of piezoelectric materials became possible with Paul Langevin's discovery in 1916 of the piezoelectric characteristics of quartz crystals. Following this discovery, it was observed that some crystalline materials demonstrate a spontaneous polarization along one axis of the crystal or ferroelectric behavior. For many years, Rochelle salt was the only crystal that was known to have this ferroelectric property [1,2]. Today, there are several hundreds of known ferroelectric materials. Generally, there is a considerable interest in ferroelectric crystals as transducer materials for their spontaneous polarization and the strong sensitivity. While solid ferroelectric materials have a higher electromechanical coupling, they are not as stable as the single crystal piezoelectric materials. Furthermore, both the poly- and the single crystals are made of fragile materials, which limits their practical size for high frequency ultrasonic applications where thin films are required.

For many years, the need for flexible and large area piezoelectric materials for ultrasonic transducers was well recognized. The large progress in this field was made in the sixties with the discovery of piezoelectricity in Polyvinylidene Fluoride (PVDF) [3, 4]. After this discovery, numerous applications of this polymer were reported and ultrasonic transducers have been demonstrated [5]. Some of the piezoelectric polymers that are known today include: PVDF co-polymers, including P(VDF-TrFE) and P(VDF-TeFE), polyparaxylene, poly-bischloromethyuloxetane (Penton), aromatic polyamides, polysulfone, polyvinyl fluoride, synthetic polypeptide and cyanoethul cellulose [6, 7].

Here, for the first time, we report on ultrasonic transducer based on glassy thin film composed of achiral ferroelectric liquid crystal polymer **Pm6R8** and 30% monomer **m6R8** [8, 9]shown in Fig.1.

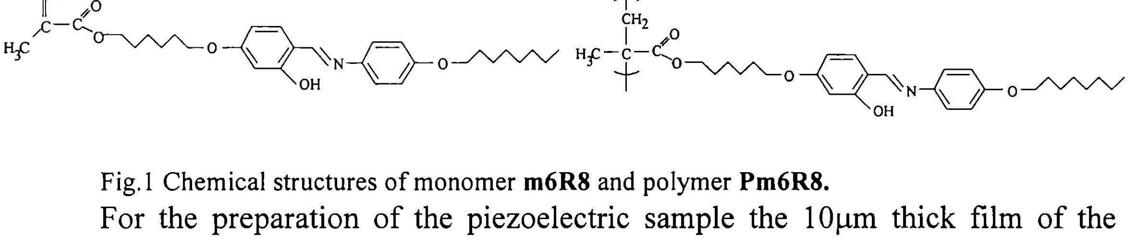
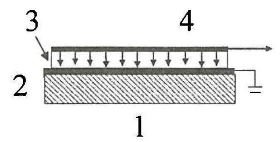


Fig.1 Chemical structures of monomer **m6R8** and polymer **Pm6R8.**

For the preparation of the piezoelectric sample the 10μm thick film of the polymer-monomer mixture has been deposited onto the ITO surface of the glass plate with subsequent treatment by corona-discharge (10 kV) at elevated temperature (100°C). After that oriented film was cooled down to room temperature and Al electrode was evaporated on the top of the film. Aluminum has a relatively low acoustic impedance as compared to other widely used metals and a direct backing of aluminum enables to form more effective broadband ultrasonic transducer. The final scheme of piezoelectric transducer operating at MHz range and its piezoelectric response are shown in Fig. 2 and Fig. 3 respectively.



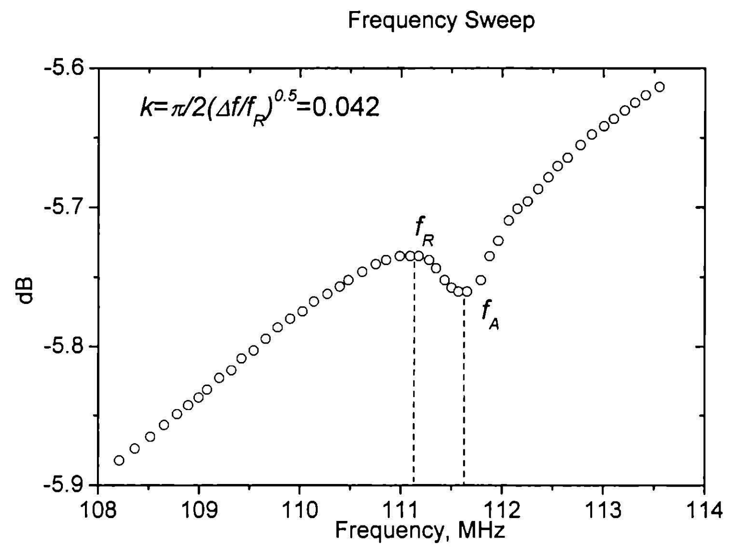


Fig. 2 Schematic diagram of piezoelectric transducer: *(1)* glass support (1 mm); *(2)* ITO; *(3)* solid ferroelectric film; *(4)* ***Al*** electrode.

Fig. 3 Amplitude of the relative electrical displacement current as the function of frequency of the alternating voltage applied to the piezoelectric film. Here k=4.2%, f_R=111,2MHz, f_A=111,68MHz are coefficient of electromechanical coupling, resonance and anti-resonance frequencies respectively. The experiment has been carried out at room temperature.

The measuring of the resonance and anti-resonance frequency allows us to calculate the electromechanical factor k to be 4.2%. Broadband transducers can be made with such films in the thickness range of 1 to 100 μm and the film low impedance enables a direct coupling to water. The low acoustic impedance of this polymer makes it attractive to medical applications of ultrasonic imaging. In principle the transducer can be coupled directly to the patients' skin or eye with minimum discomfort while maintaining an effective sound transmission to the test area.

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